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(54) TARGET SEEKING GYRO

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ABSTRACT OF THE DISCLOSURE

This invention relates to a radiation responsive homing device a target sensing and phase indicating scanning apparatus. It includes a gyro having a rotor adapted to rotate about a gyro spin axis, and a reflecting means carried by the rotor. A radiation sensitive detector is mounted in the device to receive radiation reflected from the reflecting means. Angle detection means rotate with the rotor to vary the phase of flux of radiation which is received from a target and reflected by the reflecting means onto the radiation sensitive detector depending on the direction of deviation of the gyro rotor axis from alignment with a line of sight from the device to the target. When the gyro rotor axis is not aligned to point at the target, the phase of the signal from the detector due to these flux variations corresponds to the direction of deviation of the gyro rotor axis from alignment with the line of sight.

This application is a divisional of application Serial No. 792,156 filed February 9, 1960, entitled "Target Seeking Gyro".

This invention relates to a target sensing and phase indicating scanning apparatus in a radiation responsive homing device. Such a homing device may be utilized, for example, to steer an air-to-air missile or the like along a course calculated to cause the missile to collide with a radiation emitting target, such as jet aircraft tailpipes or exhaust stacks on a propeller type plane which are sources of infrared energy.

It is an object of this invention to provide a target sensing and phase indicating scanning apparatus for producing a signal indicative of the position of the target as viewed from the homing device and substantially unaffected by attitude variations, such as rolling movements, of the supporting structure, such as a missile.

According to the invention the target sensing and phase indicating device includes a rotor adapted to rotate about a gyro spin axis, a reflecting means carried by the rotor, a radiation sensitive detector mounted in the homing device to receive radiation reflected from said reflecting means, angle detection means rotating with said rotor for varying the phase of flux of radiation received from a target and reflected by said reflecting means onto said radiation sensitive detector depending on the direction of the deviation of said gyro rotor axis from alignment with a line of sight from said device to said target, when said gyro motor axis is not aligned to point at said target, the phase of the signal from the detector due to said flux variation corresponding to the direction of deviation of said gyro rotor axis from alignment with said line of sight.

In accordance with the invention, the rotor serves a dual purpose: Its spin axis is stabilized in space and establishes a reference, which is substantially unaffected by attitude variations of the supporting structure. The reflecting and angle detection means carried by the rotor serve to scan the field of view at the rotor rotational speed. Thereby the signal from the detector is indicative of the deviation of the line of sight to the target from the stabilized rotor axis. This signal may then be used to precess the rotor spin axis towards the line of sight. The attitude of the rotor spin axis relative to the supporting structure may be picked-off to produce steering signals.

This invention will now be described with reference to the accompanying drawings, wherein:

Fig. 1 is a diagrammatic view of the forward section of a seeker assembly illustrating the operation of the invention and shown in its relationship to the forward part of an air-to-air missile;

Fig. 2 is a cross sectional view taken along line 2 - 2 of Fig. 1;

Fig. 3 is a diagrammatic view of a missile showing the various components of the guidance system in block form;

Fig. 4 is a diagrammatic view of another embodiment of the invention; and

Fig. 5 is a view as in Fig. 4 in combination with a diagrammatic view of a missile showing the various components of the guidance system in block form.

Referring to Fig. 1 of the drawings, this figure is a schematic view of a fragmentary showing of the seeker device to most simply illustrate the principle of its operation. The various parts are shown in their relative position to each other, however, some supporting structure is not shown in order to more simply show the operational parts of the device. Numeral 10 represents the nose of a missile, the forward part of the nose being transparent to allow the movable optical portion of the seeker head to scan a target. The gyro rotor is shown at 11 and, as may be seen, it is within a circular air manifold 12. The gyro rotor is pneumatically driven by air discharging through jets 13, shown in Fig. 2. The rotor carries a mirror as shown at 14 which is mounted at a small angle to the axis of the gyro and this angle may be 2 1/2°, for example. However, other angles may be used depending upon the desired position and size of the other components in the seeker device. The gyro rotor comprises a permanent magnet 22 as indicated by the pole designation N and S. The gyro rotor magnet and mirror form the movable optical portion of the seeker head.

In Fig. 1 numeral 17 designates a target which may be any source of radiation of light, heat or infrared rays, such as a jet airplane tailpipe. Numeral 18 designates diagrammatically a photocell or other radiation responsive device which receives the target signal.

Referring now to Figs. 1 and 2 of the drawings, numeral 19 designates the precessing coil, which is mounted on the gyro frame 16 by a support 24 and surrounds the rotating magnet 22, as will be explained more in detail presently. Numeral 20 designates the central bore or support for the rotor 11, engaging a central pivot point as shown at 21, aligned with the rotor axis whereby the rotor is free to rotate and be precessed with two degrees of freedom. Bore 20 and pivot 21 are shown for illustrative purposes only. In actuality a universal bearing as shown in Fig. 4, for example, or miniature gimbals would be used. The air manifold 12 has three lateral angularly spaced jets 13, as shown, whereby air or gas under pressure is discharged against scallops 26 on the rotor 11, for rotating it at high speed.

The rotor 11 carries the permanent magnet 22 which rotates with the rotor. Bore 20 is formed in the magnet 22 as shown. The rotor 11 has a depending skirt 25, as shown, so that an annular space is formed between the skirt and the magnet. The fixed precessing coil 19 is a solenoid coil disposed in this annular space mounted on frame 16 by support, not shown, leaving the rotor free to tilt through a substantial angle. Disposed below the skirt 25 in close proximity thereto are electrical pick-off coils 23 which are used in measuring the tilt of the gyro rotor by variations in their inductance. The depending skirt 25 provides a return magnetic part for the magnetic flux of permanent magnet 22 and its relative proximity to the pick-off coils 23 determines their inductance. These pick-off coils each comprise two windings in series and a plurality of them may be provided in the respective quadrants of the rotor. For simplicity, pickoff coils 23 are shown for a single plane of precession only and they are mounted on the gyro support frame 16. The pick-off coils 23 are shown by the way of example as one manner of sensing tilt of the rotor 11 and are exemplary of electrical or other means of sensing the degree of tilt without actual physical attachment thereof to the rotor. These coils control a servo-mechanism as shown in Fig. 3, which may be used to adjust the control fins of a missile, for example, to guide the missile along a pursuit course to a target.

The mirror 14 is mounted at an angle of 2 1/2° to the rotor axis, so that its optical axis is at the same angle to the gyro axis causing the reflected image of a target to travel in a circular path when the gyro rotor 11 is rotating. When the rotor axis is aligned with the line of sight to the target, the image of the target will travel along a circular path around photocell 18, whereby the photocell produces no AC current output signal. If, however, the line of sight to the target deviates from the rotor spin axis, the image of the target travels along a circular path eccentric with respect to the area of the photocell. Thereby an AC output signal is produced by the photocell, the amplitude of this AC output signal being indicative of the amount of angular deviation of the line of sight from the rotor spin axis and the phase of the AC output signal being indicative of the direction of the deviation about the rotor spin axis. The signals thus obtained are applied to coil 19. Coil 19 generates an axial alternating magnetic field, magnet 22 rotating in this alternating magnetic field. A torque is periodically exerted on the rotor 11. The moment at which the torque is exerted by the magnetic field depends on the direction of the target deviation. The photocell signal is applied through appropriate amplifier and phase adjusting means 25, if necessary, to coil 19 in such a manner that the gyro rotor is precessed by the torques in the direction of the target deviation to reduce the photocell signals to zero.

If the rotor spin axis has been aligned with the line of sight to the target and the gyro rotor thus rotates about an axis which is at an angle to the missile axis, the orientation of the gyro rotor 11 relative to the missile is picked-off and the steering system of the missile is actuated by the signals thus received to align the axis of the missile with the rotor spin axis. Thus the missile is held on a pursuit course towards the target.

Referring now to Fig. 3, the inclination of the rotor 11 with respect to the missile longitudinal axis causes variations of the inductances of the pick-off coils 23. The pick-off coils are connected in bridges 70, 71 which are unbalanced, in accordance with the components of the rotor inclination with respect to two mutually vertical planes of the missile. The bridges 70, 71 are fed by a 2.000 cycle per second generator and provide signals of 2.000 cycles per second, the amplitude of which is dependent on the bridge unbalance. These signals are applied to servo-motors 93 and 94, respectively, through amplifiers 111 and 113, respectively, to actuate the elevators and rudders, respectively.

Referring to Fig. 5, this figure shows schematically a preferred form of the invention calculated to realize certain advantages.

In Fig. 5 the gyro rotor indicated at 100 comprises a permanent magnet 101 as in the first embodiment. It has also a skirt 102 providing a return magnetic path. Precessing coil 119 is mounted on base 122 by support 124. Numeral 114 designates a central bearing support for the gyro rotor which is in the form of a spherical ball and the rotor is mounted to move universally about this ball. The central bore of the rotor engages ball bearings 106 which are positioned between the central bore and the spherical ball 114. Fixed spherical ball and central support 114 are mounted on base 122. The rotor carries a tilted concave mirror 103, and numeral 109 designates support rods to which are attached plane or convex mirrors 110 on the axis of the rotor mounting. A photocell or radiant energy sensitive element 117 such as a lead sulfide cell is mounted on the spherical ball 114 on the axis of rotation of the gyro. However, photocell 117 is on the fixed support and does not rotate or move with the gyro. The mirror assembly rotates with the gyro rotor and moves therewith. Infrared radiation, for example, from a target passes through the transparent nose 120 of the seeker head and is reflected off concave mirror 103 and plane mirror 110. The mirror assembly on the gyro lines up with the line from the seeker to the target (line of sight) and the reflected target image surrounds the photocell. If the gyro axis deviates from pointing to the target the radiation from the target will impinge on the photocell to produce a signal similar to the signal from photocell 18 in Fig. 1 to 3.

This signal is applied to an amplifier 25 similar to Fig. 3 and causes the gyro to be precessed in a straight line by precessing coil 119 so that the gyro axis will realign with the line to the target. When the gyro axis does not coincide with the longitudinal axis of the missile (i. e. the longitudinal axis of the target seeker device) the gyro rotor is tilted. The amount the rotor has tilted is sensed by the pick-off coils 123, which are mounted behind the rotor skirt, by variation in their inductance caused by their proximity to the rotor skirt. The pick-off coils cause actuation of the missile fins (elevator and rudder) in the same way as described with reference to Fig. 3. Corresponding elements have the same reference numeral in Fig. 3 and Fig. 4.

SUPPLEMENTARY DISCLOSURE

In addition to the subject matter mentioned in the principal disclosure, this invention relates to another embodiment of the device shown in the annexed drawings wherein:

Fig. 6 is a schematic of the seeker assembly which, when combined with a single amplifier, provides a target seeking mechanism of the present invention;

Fig. 7 is a cross-section of the gimbal mounting system, taken along line VII-VII of Fig. 6;

Fig. 8 is a front view of a chopper disc or reticle used with the scanner mechanism of Fig. 6 and 7;

Fig. 9 is a graphical representation of the signal obtained from the chopper disc or reticle of Fig. 8;

Fig. 10 is a graphical representation of the signal generated by the chopper disc of Fig. 8 including the signal envelope thereof; and

Fig. 11 is a schematic of the phase detector circuit used with the embodiment of the invention in Figs. 6, 7, 8 and 9.

Figs. 6 and 7, together with Figs. 8, 9, 10 and 11, represent another practical embodiment of the tracking arrangement 500 of this invention for use in a missile for tracking a target T. In this tracking system 500, the forces of gravity are supported by an internal gimbal ring system 502, which is designed to have a minimum mass and minimum moments of inertia in order to duplicate the conditions of a freely spinning assembly isolated from external forces as nearly as possible, that is, external forces other than the precessional torques generated by the precession coil 548.

In this tracking arrangement 500, the parallel rays of radiation from a distant target T pass through a nose or radome 504 of a missile and are reflected by a primary mirror 506 of a Cassegrainian mirror system to a secondary mirror 508 thereof. The rays of radiation from the mirror 506 are caused to converge at a chopper disc or reticle 516 mounted on support 518 after passing through a quartz insert 512. An infrared filter 517 is positioned adjacent to the chopper disc or reticle 516 in order to protect the light-sensitive detector 520 from unwanted radiations and to allow it to concentrate on the desired target T. The rays of radiation then diverge before impinging on an electric detector 520.

The scanner-tracker system 500 is shown mounted on a sleeve 524, which at its upper end is provided with the previously mentioned quartz insert 512, having a post 510 extending therefrom for mounting the secondary mirror 508 of the Cassegrainian mirror system. A sunshade is mounted on the periphery of mirror 508.

The detector 520 is mounted in the recessed end of hollow post 521, and it is provided with a pair of leads, as shown, which can be connected to the electrical system as described for the other embodiments of the invention.

As shown in Figs. 6 and 7, the gimbal assembly, which is indicated generally by reference numeral 502, consists of inner and outer gimbal rings 538 and 532 mounted as shown. A stub shaft 546 is secured to opposite sides of post 521, with a miniature bearing 544 being provided on each shaft 546. The inner gimbal ring 538 is provided with apertured bosses 542 for mounting of the miniature bearings 544.

At 9o° positions to the miniature bearings 544 and the mountings for the inner gimbal ring 538, there are provided stub shafts 540 on the outer surface of the inner gimbal ring 538 and on opposite sides thereof for mounting the miniature bearings 536 in apertured bosses 534 provided in the outer gimbal ring 532 as shown best in Fig. 7. Bearings 528 are used to mount the outer gimbal ring 532 to a cylindrical insert 524 and cylindrical sleeve 514 for receiving the gimbal bearing assembly 502 in its lower end. Lock rings 526 and 530 are used to retain the gimbal bearing assembly 502 in the lower end of the sleeve 514.

A permanent magnet 522, as previously described in connection with the other embodiments of the invention, is mounted on the lower end of the sleeve 514, and its ends are spaced from the precession coil 548. The precession coil 548 consists of two coils wound to operate in push-pull, and in actuality consists of two coils wound one on top of the other and 180° out of phase. These precession coils 548 are illustrated in the electrical schematic of Fig. 11.

In the embodiment of the scanning tracking system 500 of the invention, the precessional torque is again the interaction of the magnetic field generated by currents in the precession coil 548 with the permanent magnet 522. The orientation of the permanent magnet 522 with respect to the chopping disc or reticle 516 must be arranged in such a manner that the torques precess the gyro assembly toward the source of radiation indicated by the target T.

The external forces against which the gyro assembly must be protected are aerodynamic forces, or interactions of gravity through coupling with the gimbal assembly 502, or off-center location of the center of gravity with respect to the pivot point and frictional torques which might be generated in the gimbal assembly 502.

The purpose of the central support or post 521 is to hold the light-sensitive detector 520 which receives the varying light flux generated by the chopper or reticle 516 and filtered by the infrared filter 517.

This scanner tracking system shown in Figs. 6 and 7, when combined with a single amplifier, provides the target seeking mechanism, which is the subject of this invention. Since in this application the assembly is used to guide a missile, it is necessary to generate signals to control the direction of motion of the missile through pitch and yaw fins, as shown in Fig. 11.

The electrical circuitry for accomplishing this is shown in Fig. 11 wherein two sets of reference coils 850 and 852 and 854 and 856 are located circumferentially around the spinning permanent magnet 522 and in such a direction that the signals in these coils 850, 852, 854, and 856 represent the position of the magnet 522 with respect to missile coordinates.

These reference coils 850, 852, 854, and 856 are connected in the phase detector bridge circuit of Fig. 11, which includes the previously mentioned precession coils 548. These precession coils 548 have one end of each connected to the plates 804 of an amplifier and their other ends to identical phase sensitive detectors or bridge circuits 810 and 812 as shown. The currents in the precession coils 548 are equal and operate to cancel out the fields of the coils. Bridge circuit 810 is used to control the yaw fins (right-left movement), while bridge circuit 812 is used to control the pitch fins (up-down movement). Phase sensitive detector or bridge circuit 810 consists of four resistors 816, 820, 824, and 826 and four silicone diodes 814, 818, 822 and 826; while phase sensitive detector or bridge circuit 812 consists of resistors 832, 836, 840, and 844, and four silicone diodes 830, 834, 838, and 842, all connected in the detector circuits as shown in Fig. 11.

Phase detector 810 is connected by leads to the set of reference coils 850 and 852; while phase detector 812 is connected by leads to the set of reference coils 854 and 856. Bridge output resistors 846 and 848 are provided in the phase detector circuit, together with resistors 858 and 860 for adjustment of the gain variations in the magnetic amplifier circuits. Control windings 862 and 864 are provided in the phase detector circuit for the right-left magnetic amplifier and the up-down magnetic amplifier circuits. The resistors 806 and 808 of the phase detector circuit connect to a B+ power source, while the power for the filaments of the various electrical components is provided by an A+ power source.

The sets of reference coils 850 and 852, as well as 854 and 856, generate signals in the discriminator circuits of the system which, when combined with the signal occurring in the precession coils 548, generate DC signals in the coils 862 and 864. These signals interact with the currents generated in the precession coils 548, generate DC signals in the coils 862 and 864. These signals interact with the currents generated in the precession coils 548 in such a manner that they generate DC currents in the servo valve electromagnets, which generate pressures on crank arms or mechanical linkages attached to the pitch and yaw fins.

The torques generated on these pitch and yaw fins are thus proportional to the sight line rate of the tracking gyro. The torques cause the pitch and yaw fins of the missile to move into the air stream until they are balanced by the aerodynamic forces acting on the center of pressure at a distance from the hingeline. The distance of the center of pressure from the hingeline is kept large so that the lateral acceleration of the missile will be substantially proportional to the sight line rate generated by the gyro, which is proportional to the magnitude of the AC current flowing in precession coils 548.

Fig. 8 is a preferred embodiment of the chopper chopping disc 704 which is presently used in the system of Figs.

6, 7 and 11 in a practical missile. As the target image lies anywhere on this disc or reticle 704, an AC signal is generated such as shown by the signal of Fig. 10 during one-half cycle of the revolution of the disc or reticle 704. During the other half cycle, no signal is generated by the radial lines. This again results in the kind of signal shown in Fig. 10. The absolute value of this signal is shown in Fig. 9, which is a plot of the rectified output of the chopping chopper assembly as the target is moved from one side of the reticle across the center thereof to the other side. The chopper disc or reticle 704 of Fig. 8 consists of a checkerboard design, having black and white sectors shown in the half-rings 708, 710, 712, 714, 716, 718, 720, 722, 724, 726, 728, and 730 on one half of the chopper disc or reticle 704, and concentric black and white rings 704 on the other half thereof. The chopper disc 704 is so designed, therefore, that it will give fifty percent transmission of the radiation at all times on both sides thereof. It is to be noted that the signals 706A, 708A, 710A, 712A, 714A, 716A, 718A, 720A, 722A, 724A, 726A, 728A, and 730A correspond in magnitude to the size of the sectors of the half-rings in Fig. 8, that is, 706, 708, 710, 712, 714, 716, 718, 720, 722, 724, 726, 728, and 730, with the largest signal 712A corresponding to the largest sectors which are located in half-ring 712 of the chopper disc or reticle 704.

By the chequered pattern of the reticle 516 the radiation from the target image is modulated. The target image has, however, a finite size. When the target image is spaced from the edge of the reticle but is not located in the center therof, the areas of the chequered pattern will as a rule be larger than the target image, whereby the whole radiation will be modulated. When, however, the target image moves towards the edge of the reticle, where the sizes of the areas become smaller, it will overlap two or more areas at least partially of which alternatingly one is opaque and the adjacent one is transparent or vice versa. Thereby the target radiation is less intensely modulated, as the modulation is at least partly averaged, and the amplitude of the AC detector signal from photoelectric detector 520 is decreased. The more the target image approaches the center of the reticle the more will it overlap a plurality of alternatingly transparent and opaque areas in peripheral direction, whereby the amplitudes of the AC detector signals will also decrease towards the center of the reticle. A maximum sensitivity will be obtained with a target deviation therebetween.

In utilizing the scanner-tracking system 500 of Figs. 6, 7, 8, and 11 with missiles, it is assumed that the missiles are mounted in an aircraft. The pilot of the aircraft when in flight utilizes his gun sights for rough aiming of the missiles at a target, that is, for rough directing of the missiles at the target. The pilot then listens to the pilot's intercommunication telephone and nulls in on the signal until he has reached the minimum signal or null signal which corresponds to the center of the chopper disc or reticle 704 shown in Fig. 8. The pilot then presses his control button to release the missiles at the target.

When there is only a single target in the field of view of the scanner, the scanner axis will be aligned with the line of sight to this target. As long as this target is near of the edge of the field of view there will be relatively weak error signals, as the target is imaged on the edge of reticle

516 as shown in Fig. 8 and, in accordance with the diagram if Fig. 9, this will result in a relatively small amplitude of the signals produced by the photocell 520. Nevertheless, these signals cause the rotor spin axis to be precessed towards the line of sight. The more the target is moved towards the center of the scanned field of view the higher the amplitude of the error signals will be, until they then decrease from the maximum towards the center of the field of view. As, however, there will be a correcting movement as long as there is an error signal at all, the scanner axis will, eventually, become aligned with the line of sight to the target. Then the error signals will cease, but with even a small deviation of the target from the center of the field of view the amplitudes of the error signal would increase rapidly.

It be assumed, that the target has been "caught" in this manner with the error signals having become zero. If now a second target enters the field of view of the target seeking device, the target signals caused thereby will, at first, tend to deflect the target seeking device towards the new target. With such a deflection, however, the first target will start to generate target signals again tending to return the target seeking device to the first target. Due to the sensitivity decreasing towards the edge of the field of view the target signals caused by the first target have a much stronger effect than the signals from the second target located near the edge of the field of view. Therefore, the target seeking device will be substantially returned to the first target by these stronger signals. The effect of the signals caused by the second target will be overcome.

Thus once the target seeking device has caught a target in the center of its field of view, it will not be disturbed noticeably by additional signals from the edge of the field of view.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a radiation responsive homing device a target sensing and phase indicating scanning apparatus, including a gyro having a rotor adapted to rotate about a gyro spin axis, a reflecting means carried by the rotor, a radiation sensitive detector mounted in said device to receive radiation reflected from said reflecting means, angle detection means rotating with said rotor for varying the phase of flux of radiation received from a target and reflected by said reflecting means onto said radiation sensitive detector depending on the direction of the deviation of said gyro rotor axis from alignment with a line of sight from said device to said target, when said gyro rotor axis is not aligned to point at said target, the phase of the signal from said detector due to said flux variation corresponding to the direction of deviation of said gyro rotor axis from alignment with said line of sight.

2. In a radiation responsive device as defined in claim 1, wherein said angle detection means comprises an optical element in said reflecting means arranged to cause the reflections of said target to move in a circular path, said circular path normally surrounding said radiation sensitive cell, when the gyro axis is aligned to point at said target, said circular path deviating so as to impinge upon part of said radiation sensitive cell when said gyro rotor axis is not aligned to point at said target, the angular phase position of the point of interception of said reflector target radiation upon said radiation sensitive element and the consequent signal pulse corresponding to the direction of deviation of said gyro rotor axis from alignment with said line of sight.

3. In a radiation responsive homing device, a target sensing and phase indicating scanning apparatus including a gyro having a rotor, a reflecting means carried by the rotor, a radiation sensitive cell mounted in said device in a position to receive light reflected from said reflecting means, said reflecting means rotating with said rotor and operative to reflect any image of a target received by said reflecting means rotating with said rotor to cause the reflections of said target to move in a circular path, said circular path normally surrounding said radiation sensitive cell when the gyro rotor axis is aligned to point at said target, said circular path deviating so as to impinge upon part of said radiation sensitive cell when said gyro rotor axis is not aligned to point at said target, the angular phase position of the point of interception of said reflected target radiation upon said radiation sensitive element and the consequent signal pulse corresponding to the direction of deviation of said gyro rotor axis from alignment with a line of sight from said device to said target.

CLAIMS SUPPORTED BY SUPPLEMENTARY DISCLOSURE

4. In a radiation responsive device as defined in claim 1, wherein said angle detection means comprise a reticle rotative with said rotor and located in front of said detector as viewed in the direction of incident radiation, said reflecting means forming an optical system having its optical axis aligned with said gyro rotor axis and having its focal plane in the plane of said reticle, said reticle forming a pattern of opaque and transparent areas to modulate the radiation from said target impinging on said detector such as to generate at said detector a signal having an amplitude indicative of the radial deviation of the target from the rotor spin axis and having a phase indicative of the direction of said radial deviation.

5. In a radiation responsive device as defined in claim ~~3~~4, wherein the amplitude of said signal as a function of said deviation of the target from the gyro rotor spin axis is zero with zero deviation, increases to a maximum with increasing deviation, and decreases from said maximum with further increasing deviations, if the image of the target deviates towards the edge of said reticle.

6. In a radiation responsive device as claimed in claim 4, wherein said reticle comprises a chequered pattern on substantially one half of the reticle, the areas of this pattern being defined by radii and concentric circles, the size of these areas decreasing towards the edge of the reticle, and a pattern comprising a system of alternating transparent and opaque substantially semicircular areas on the remaining portions of the reticle, the mean transparency being substantially the same on both halves of the reticle.

FIG. 1

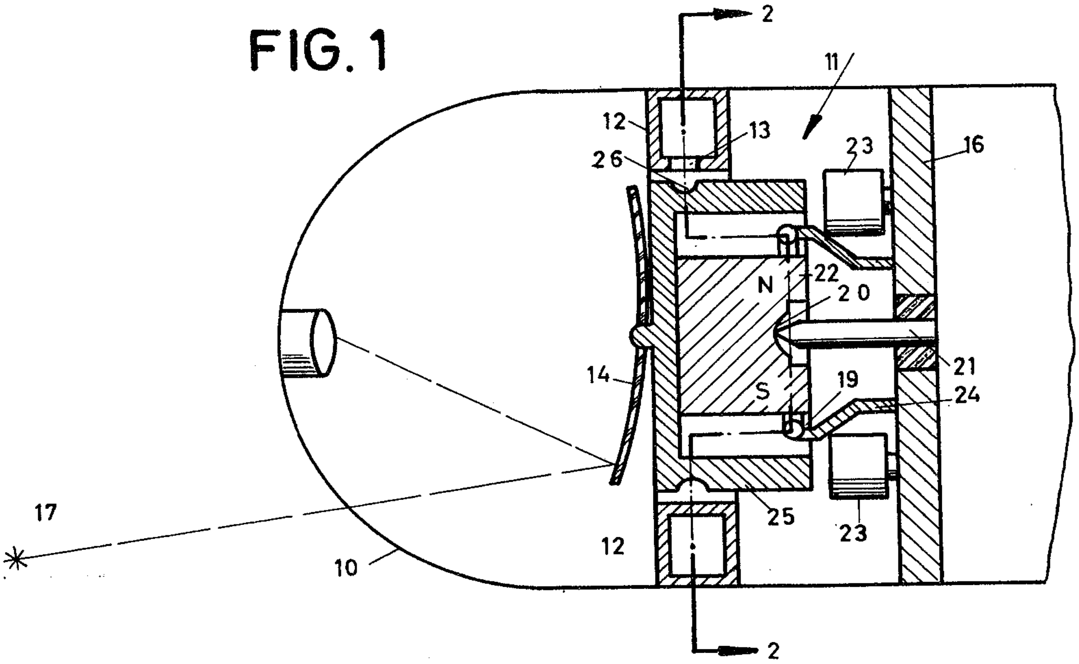
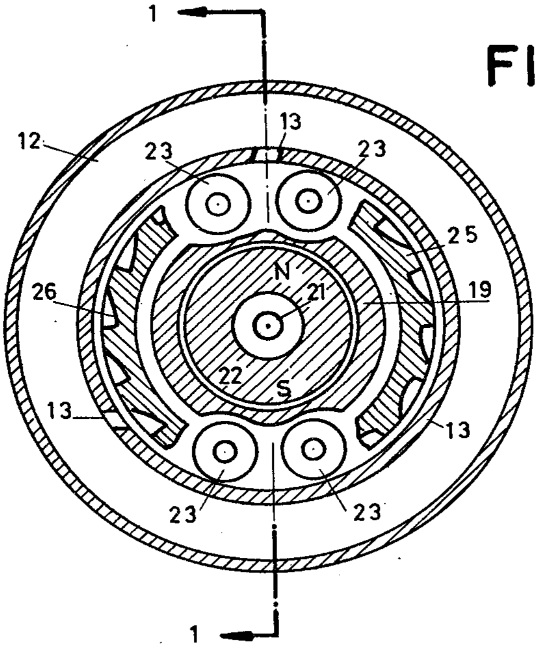


FIG. 2



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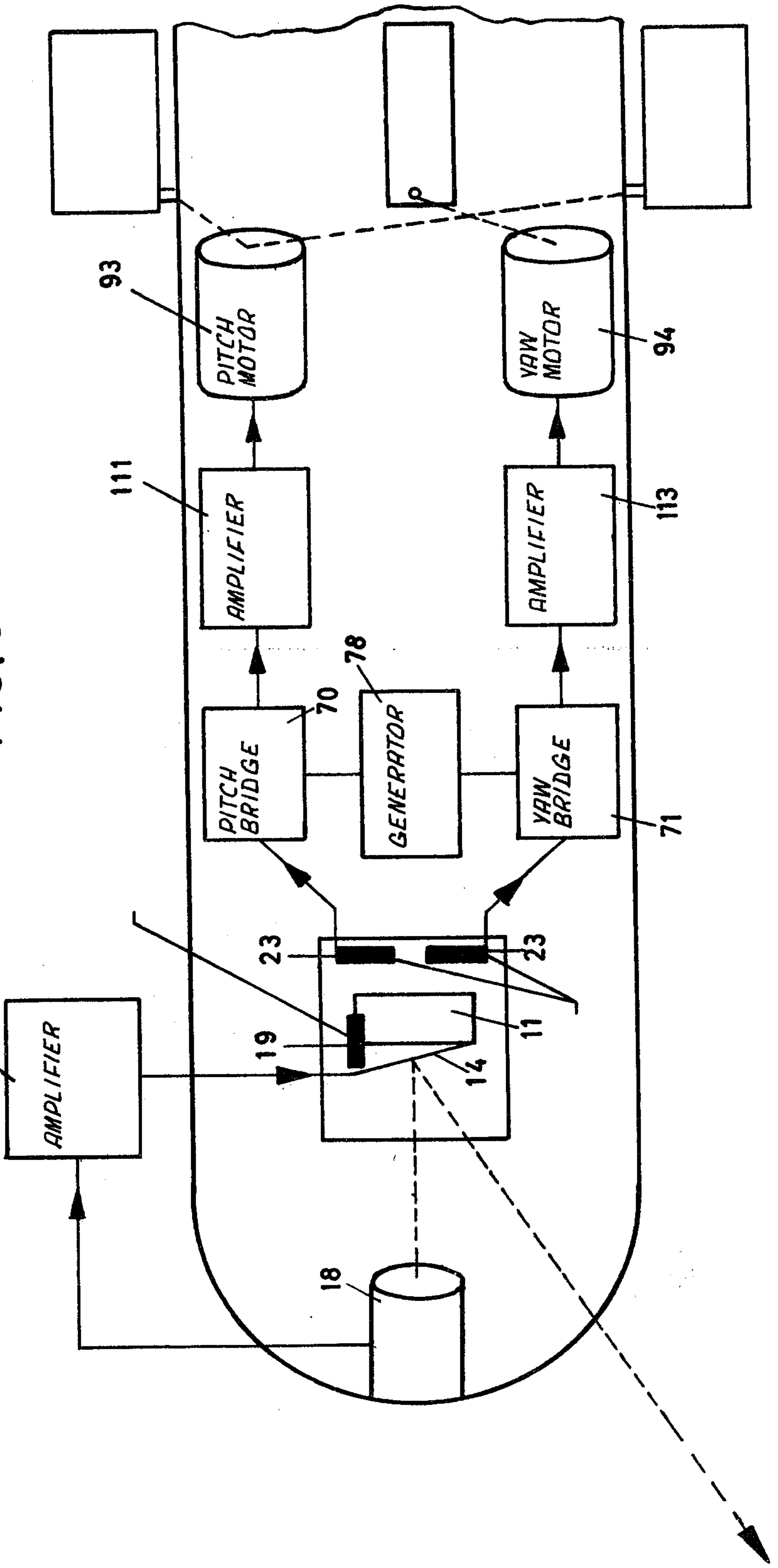
[illegible]

FIG. 3



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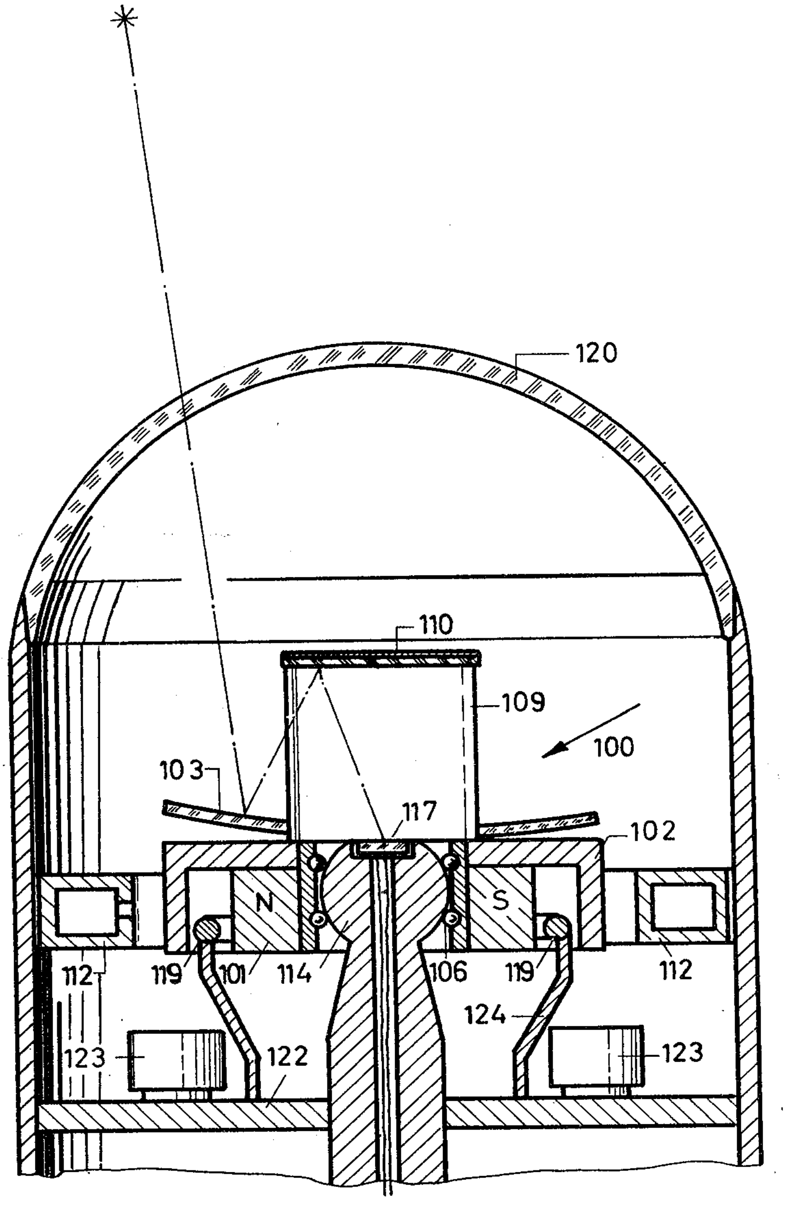

FIG. 4

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217,141

FIG. 5

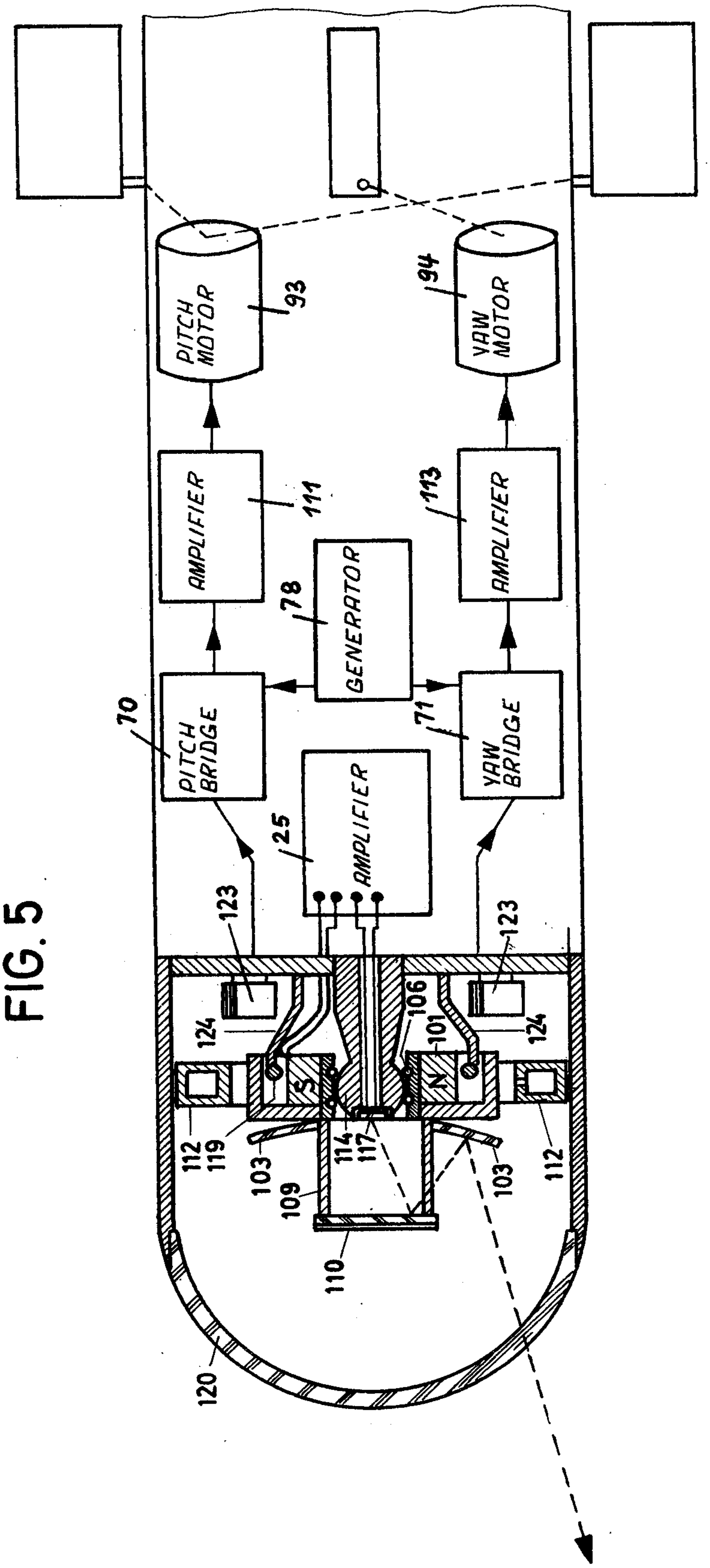

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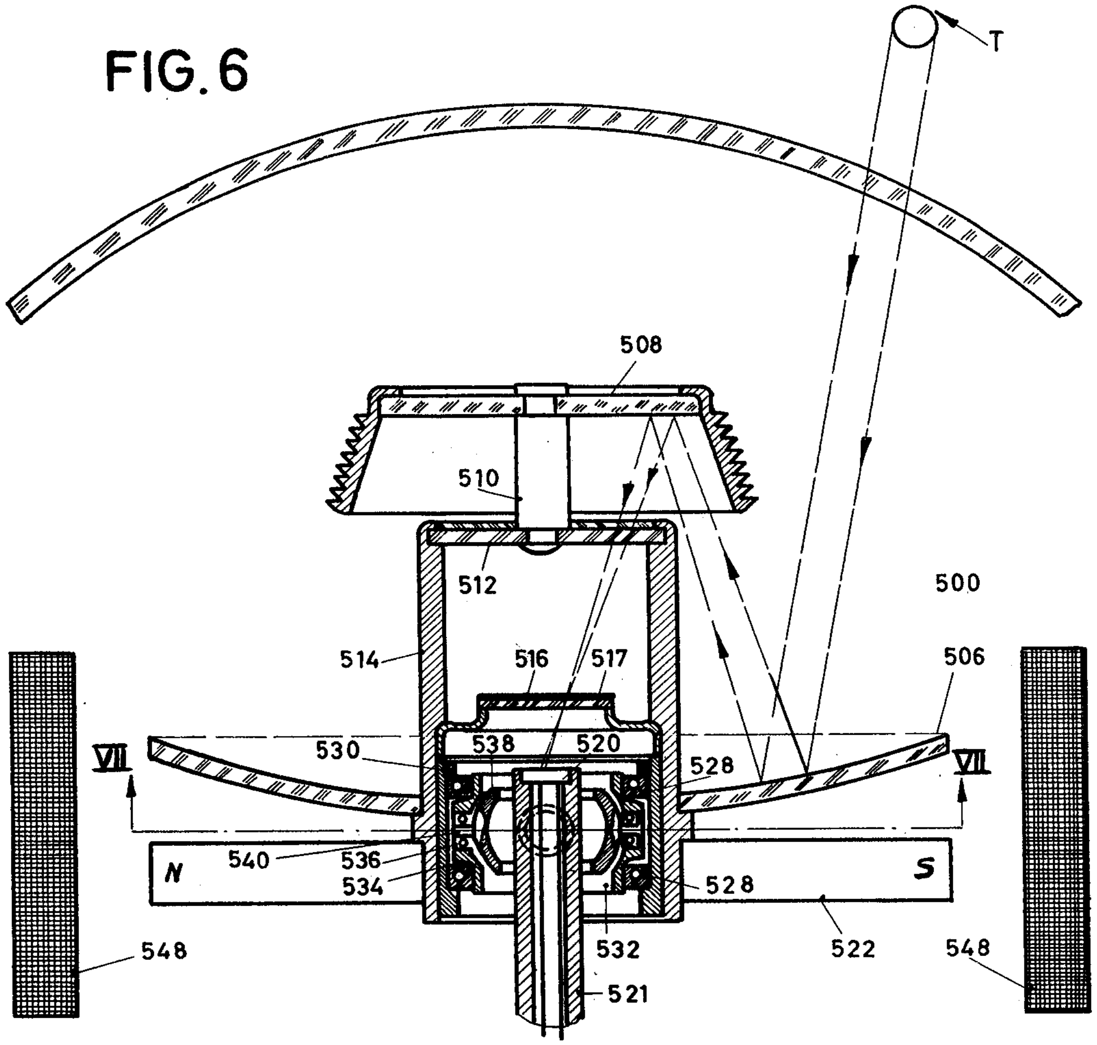
FIG. 6



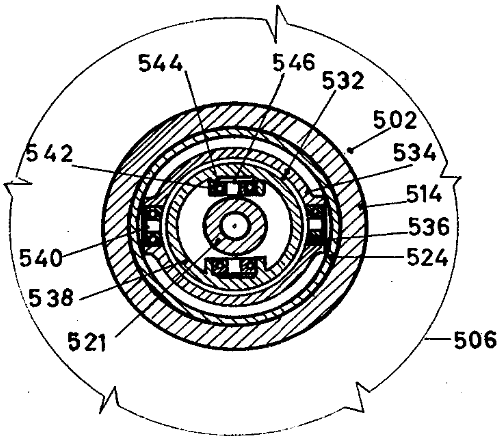


FIG. 7

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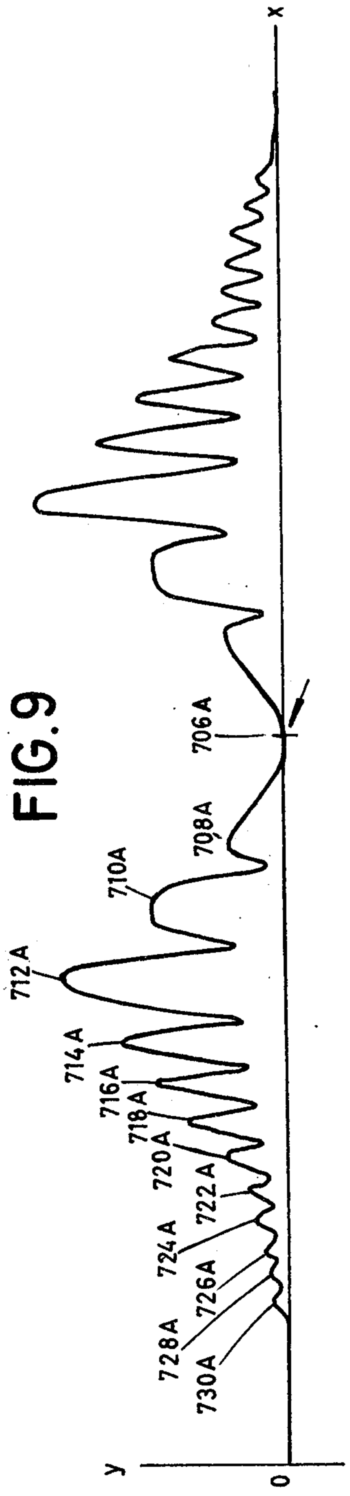
FIG.9



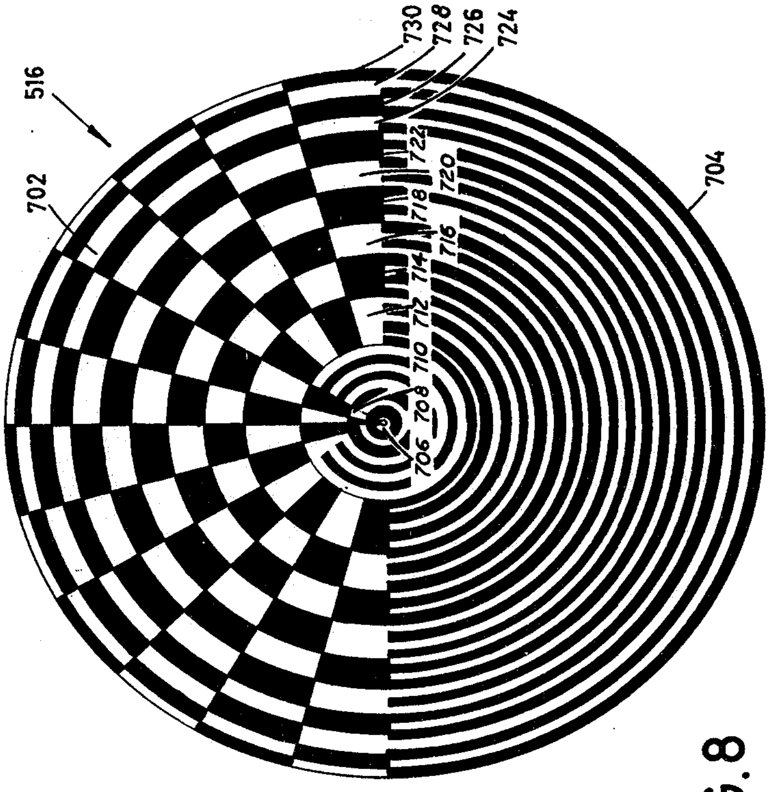


FIG.8

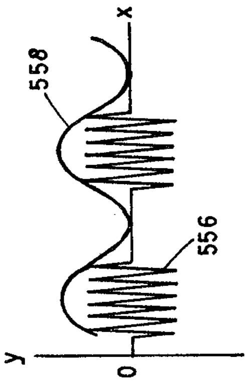


FIG.10

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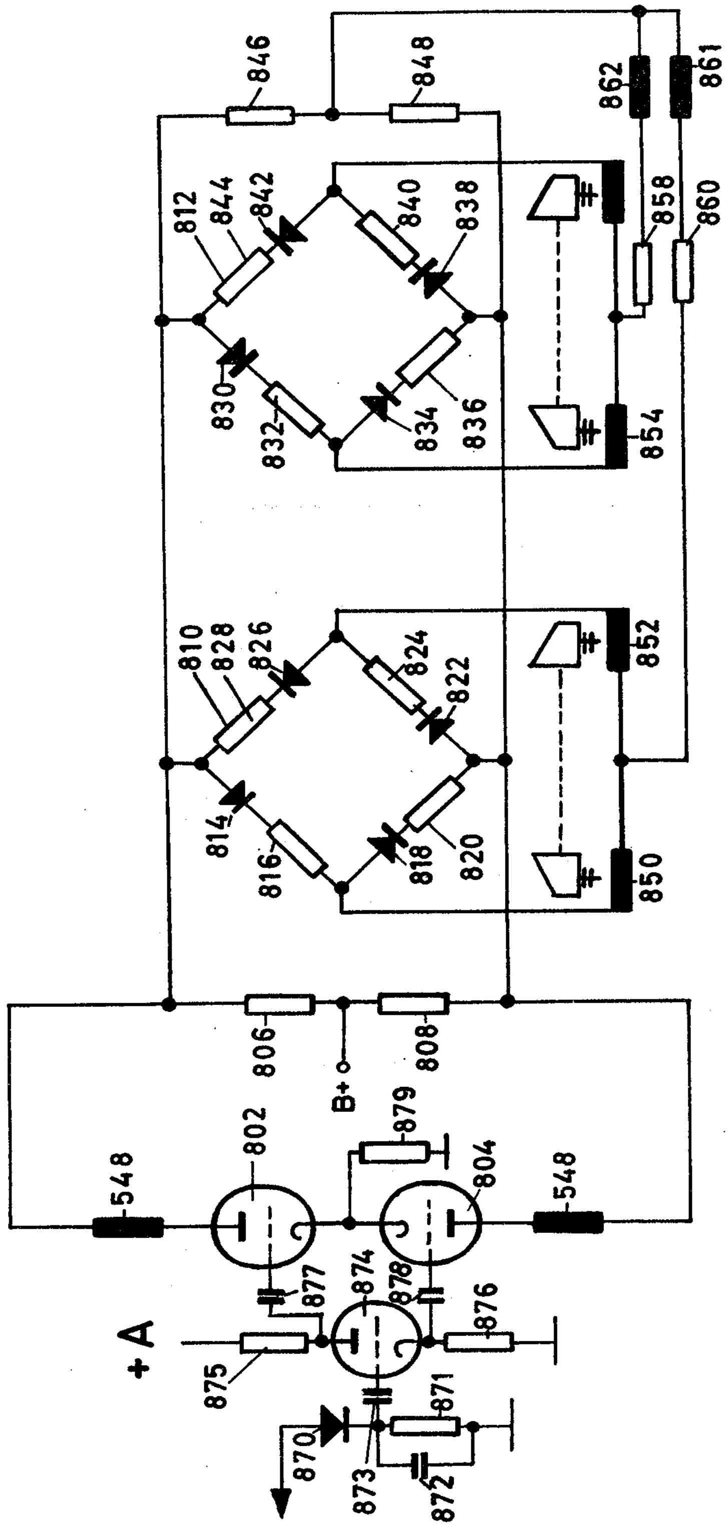
FIG.11



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